REPORT DOCUMENTATION PAGE		FORM APPROVED OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE Oct. 14, 1998	3. REPORT TYPE AND DATES COVERED Annual, 10/1/97 – 9/30/98

4. TITLE AND SUBTITLE OF REPORT
High Speed, Numerically Superior Signal Processing Algorithms Using QRD and Delta Operator

5. FUNDING NUMBERS
N00014-96-1-0241

6. AUTHOR(S)

H. (Howard) Fan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

University of Cincinnati
Dept. of ECECS, ML 30
Cincinnati, OH 45221

8. PERFORMING ORGANIZATION REPORT NUMBER:

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
Attn.: Dr. Clifford Lau
800 North Quincy St.
Arlington, VA 22217-5660

10. SPONSORING/MONITORING AGENCY REPORT NUMBER:

11. SUPPLEMENTARY NOTES:

12a. DISTRIBUTION AVAILABILITY STATEMENT

Approved for Public Release

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Several research topics related to the delta-operator have been studied. First, our research on the delta-operator based efficient stability tests is being wrapped up and concluded. We have revised and published a few papers on various aspects of this topic. Second, we have completed the development of a delta-operator based least squares lattice algorithm, which is computationally efficient and numerically better than an existing algorithm. The work is completed during this period and some papers have been submitted/published. Third, we continued to work on the "generalized delta operator" in the identification of continuous-time AR process parameters. We have studied the use of the generalized delta operator in a noisy environment, and have investigated integrated sampling and its effectiveness in coping with noise. Other topics such as blind equalization and wavelet based time-varying system modelling have also been studied.

14. SUBJECT TERMS

delta operator, stability tests, lease squares lattice, continuous-time AR processes, blind equalization

15. NUMBER OF PAGES: 5

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT: Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT SAR

University of Cincinnati
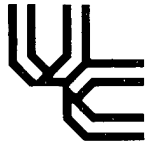
Department of Electrical & Computer
   Engineering and Computer Science
University of Cincinnati
PO Box 210030
Cincinnati OH 45221-0030

814 Rhodes Hall
Fax (513) 556-7326

October 14, 1998

Defense Technical Information Center
8725 John J. Kingman Rd.
STE 0944
Ft. Belvoir, VA 22060-6218

Dear Sir/Madam:

Enclosed please find two copies of the annual project report for ONR grant N00014-96-1-0241 with an SF-298 form for each. The grant has been extended with no additional cost to September 30, 1999. A final report is not due until then. Therefore this one serves as an annual report. Copies of submitted/published papers acknowledging ONR support under this project are available upon request. Please contact me at (513) 556-4765 or by e-mail at "h.fan@uc.edu" if you have any questions.

Thank you very much.

Sincerely yours,

H. (Howard) Fan
Professor

enclosure

OFFICE OF NAVAL RESEARCH
ANNUAL PROJECT REPORT

Contract: N00014-96-1-0241
Title: High Speed, Numerically Superior Signal Processing
          Algorithms Using QRD & Delta Operator
PI: Dr. H. (Howard) Fan
Period: 1 October 1997 through 30 September 1998

This period is the third annum under this grant. The grant has been
extended (no additional cost) to September 30, 1999. Therefore a
final report will be submitted by then. This is thus only an annual
report. Our efforts during this annum are concentrated on the
following activities:

1. Delta Operator Related Research: The PI organized an invited
    session, Delta operator in Systems, Control, and Signal Processing,
    in the 36th IEEE Conference on Decision and Control held in San
    Diego in December 1997. Various subtopics using the delta
    operator were covered in this session. Our contributions in
    this session and in this subject in general are as follows.

a. Continue to wrap up and disseminate the delta-operator based
    stability test algorithms. We have revised and published some
    previously submitted journal papers (B1 and B2), and have
    published a conference paper (H2). A book on this subject is
    currently in writing.

b. We have developed a delta operator based least squares lattice
    algorithm. This algorithm uses both the forward and the backward
    delta operators. A continuous-time limit can be achieved with
    this algorithm. This is quite different from an existing delta
    operator based least squares lattice algorithm, which only uses
    the forward delta operator. In fact this existing algorithm does
    not have a continuous-time limit. Our simulations show that our
    new algorithm outperforms both the traditional shift operator
    based least squares lattice and the existing delta operator based
    algorithm in terms of numerical properties under finite precision
    implementations. This work is being published in a conference
    paper (I3) and a journal paper submission (A1).

c. The cooperative research on the "generalized delta operator" with
    the Swedish researchers led by Prof. Soderstrom turns out to be
    very successful. We concentrate our study on identification of
    continuous-time ARX model parameters using discrete-time data and
    either the delta operator or the generalized delta operators. We
    have obtained further results using bias compensation and a "no
    shift" method (H1 and I2). We have also investigated integrated
    sampling (I1). A comprehensive study of these methods in presence
    of additive noise and ways to cope with it is summarized in a
    journal paper submission (A2).

2. Blind Equalization. This work is a continuation of our previous
    work started by a former PhD student who was supported by the
    AASERT program. That work is now published (B3). We have further

developed a QR factorization based blind equalization algorithm (A3) which is computationally much more efficient than most existing subspace based methods. We have also developed a general Newton-like recursive algorithm for complex variables (A4). The existing Newton algorithm is for real variables. When the variables are complex, the existing Newton algorithm does not apply, especially to the Hessian matrix. We have extended it to the complex case. This algorithm has wide applications whenever the involved variables are complex. One such application is in blind equalization which is discussed in the paper submission (A4). We have further studied the global convergence issue of some adaptive blind equalizers (A5). Furthermore, we have come up with an innovative way of constructing a reference signal in the blind setting. Thus many non-blind fast algorithms can be used in the blind way. This saves computation and speeds up convergence. This work is summarized in (A6) and (I4). A provisional patent application has also been filed on this method (F1).

3. Continue to work on other aspects which were initiated before. We revised a number of our previous paper submissions on various topics. One of them is on a modified normalized lattice, which is now accepted. Another one is on the robustness issue in linear time-varying system modeling using wavelets, which is also accepted. Yet another one is on delta operator stability test. And finally a paper on new results in parameter identification of continuous-time AR processes, which is also accepted. These are not included in the attached publications/ presentations list, since their submissions have been previously reported.

OFFICE OF NAVAL RESEARCH
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
for
1 October 1997 through 30 Sept. 1998

Contract/Grant Number: N00014-96-1-0241

Contract/Grant Title: High Speed, Numerically Superior Signal Processing
Algorithms Using QRD and Delta Operator

Principal Investigator: Dr. H. (Howard) Fan

Mailing Address: Dept. of Electrical & Computer Engineering
and Computer Science
M.L. 30
University of Cincinnati
Cincinnati, OH 45221

Phone Number (with area code): (513) 556-4765

E-Mail Address: h.fan@uc.edu

a. Number of Papers Submitted to Refereed Journals but not yet published: __6__

b. Number of Papers Published in Refereed Journals: __3__

c. Number of Books or Chapters Submitted but not yet Published: __0__

d. Number of Books or Chapters Published: __0__

e. Number of Printed Technical Reports & Non-Refereed Papers: __0__

f. Number of Patents Filed: __1__

g. Number of Patents Granted: __0__

h. Number of Invited Presentations at Workshops or Prof. Society Meetings: __2__

i. Number of Presentations at Workshops or Prof. Society Meetings: __4__

j. Honors/Awards/Prizes for Contract/Grant Employees: __0__

k. Total number of Graduate Students and Post-Docs Supported at least 25%,
on this contract/grant:

Grad Students _3_   and Post Docs _0_

How many of each are females or minorities? (These
6 numbers are for ONR's EEO/Minority Reports:
minorities include Blacks, Aleuts Amindians,
etc. and those of Hispanic or Asian extraction/
nationality. These Asians are singled out to
facilitate meeting the varying report semantics
re "under-represented").

[Grad Student Female   ____
] [
] [Grad Student Minority ____
] [
] [Grad Student Asian e/n _3_
] [
] [Post-Doc Female   ____
] [
] [Post-Doc Minority   ____
] [
] [Post-Doc Asian e/n   ____

PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
for
1 October 1997 through 30 September 1998

Contract/Grant Number: N00014-96-1-0241
Contract/Grant Title: High Speed, Numerically Superior Signal
                        Processing Algorithms Using QRD and Delta
                        Operator
Principal Investigator: Dr. H. (Howard) Fan
Mailing Address: Dept. of Electrical & Computer Engineering
                            and Computer Science
                        M.L. 30
                        University of Cincinnati
                        Cincinnati, OH 45221
Phone Number: (513) 556-4765
E-mail Address: h.fan@uc.edu

A. PAPERS SUBMITTED TO REFEREED JOURNALS

1. P. De and H. Fan, "A delta least squares lattice algorithm for
   fast sampling," IEEE Trans. on Signal Processing, in review.

2. H. Fan, T. Soderstrom, and Y. Zou, "Continuous-time AR process
   parameter estimation in presence of additive white noise," IEEE
   Trans. on Signal Processing, now accepted.

3. X. Li and H. Fan, "QR factorization based blind channel
   identification and equalization with second order statistics,"
   IEEE Trans. on Signal Processing, in review.

4. G. Yan and H. Fan, "A Newton-like algorithm for complex variables
   with applications in blind equalization," IEEE Trans. on Signal
   Processing, in review.

5. G. Yan, H. Fan, and Z. Ding, "On global convergence of blind
   adaptive equalizers," IEEE Trans. on Signal Processing, in review.

6. G. Yan and H. Fan, "Fast algorithms for blind equalization,"
   IEEE Trans. on Signal Processing, in review.

B. PAPERS PUBLISHED IN REFEREED JOURNALS

1. H. Fan, "A normalized Schur-Cohn stability test for the delta-
   operator based polynomials," IEEE Trans. on Automatic Control,
   vol. 42, no. 11, pp. 1606-1612, Nov. 1997.

2. H. Fan, "On delta-operator Schur-Cohn zero-location tests for
   fast sampling," IEEE Trans. on Signal Processing, vol. 46, no. 7,
   pp. 1851-1860, July 1998.

3. V. Shtrom and H. Fan, "A new class of zero-forcing cost functions
   in blind equalization," IEEE Trans. on Signal Processing, vol. 46,
   no. 10, pp. 2674-2683, Oct. 1998.

F. PATENTS FILED

1. G. Yan and H. Fan, "A method and system for fast blind adaptive equalization," Provisional patent appication filed by Frost and Jacobs LLP on behalf of University of Cincinnati.

H. INVITED PRESENTATIONS AT PROFESSIONAL SOCIETY MEETINGS

1. T. Soderstrom, H. Fan, B. Carlsson, and M. Mossberg, "Some approaches on how to use the Delta operator when identifying continuous-time processes," Proc. 36th IEEE Conference on Decision and Control, pp. 890-895, San Diego, Dec. 1997.

2. H. Fan, "Efficient stability tests: Unifying theory and further results using the Delta operator," Proc. 36th IEEE Conference on Decision and Control, pp. 896-901, San Diego, Dec. 1997.

I. PRESENTATIONS AT PROFESSIONAL SOCIETY MEETINGS

1. H. Fan and T. Soderstrom, "Parameter estimation of continuous-time AR processes using integrated sampling," Proc. 36th IEEE Conf. on Decision and Control, pp. 3474-3475, San Diego, Dec. 1997.

2. H. Fan, T. Soderstrom, M. Mossberg, B. Carlsson, and Y. Zou, "Continuous-time AR process parameter estimation from discrete-time data," Proc. IEEE Intl. Conf. on Acoust., Speech, Signal Processing, vol. 4, pp. 2333 - 2336, Seattle, Washington, May 1998.

3. P. De and H. Fan, "A delta least squares lattice algorithm for fast sampling," Proc. IEEE Intl. Conf. on Acoust., Speech, Signal Processing, vol. 3, pp. 1373 - 1376, Seattle, Washington, May 1998.

4. G. Yan and H. Fan, "Fast algorithms for blind adaptive equalizers," Proc. 1998 IEEE Digital Signal Processing Workshop, Bryce Canyon, Utah, August 1998.

K. GRADUATE STUDENTS SUPPORTED UNDER THE CRP FOR THIS PERIOD

1. P. De, Ph.D., completed September 1998.

2. G. Yan, Ph.D. candidate (partially supported).

3. X. Li, Ph.D. candidate (partially supported).